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Strong field spectroscopy of electron dynamics: from laser filaments to strongly correlated solids

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Interaction of intense infrared laser light with matter, be it gases or solids, leads to rich and highly nonlinear electron dynamics. This talk will cover two very different examples. The first deals with gases, the second with strongly correlated solids. In atoms, unusual states can be created by light fields with strengths comparable to the Coulomb field that binds valence electrons in atoms. One would expect that such fields would easily set a valence electron free, perhaps within a single laser cycle. Yet, since late 1980s, theorists have speculated that atomic states become more stable when the strength of the laser field substantially exceeds the Coulomb attraction to the ionic core. The electron becomes nearly but not completely free: rapidly oscillating in the laser field, it still feels residual attraction to the core, which keeps it bound. I will describe a combination of experimental and theoretical results which show that these states arise not only in isolated atoms, but also in gases at and above atmospheric pressure, where they can act as a gain medium during laser filamentation. Using properly shaped laser pulses, gain in these states can be achieved within just a few cycles of the guided field, leading to amplified emission in the visible, at lines peculiar to the laser-dressed atom. Our work SUGGESTS that these unusual states of neutral atoms can be exploited to create a general ultrafast gain mechanism during laser filamentation. The second brings together two topics that, until very recently, have been the focus of intense but non-overlapping research efforts. The first concerns high harmonic generation in solids, which occurs when intense light field excites highly non-equilibrium electronic response in a semiconductor or a dielectric. The second concerns many-body dynamics in strongly correlated systems such as the Mott insulator. Using theorists model of a strongly correlated solid: the Hubbard model, we show that high harmonic generation can be used to time-resolve ultrafast many-body dynamics associated with optically driven phase transition, with accuracy far exceeding one cycle of the driving light field. These results pave the way for time-resolving highly non-equilibrium many body dynamics in strongly correlated systems, with few femtosecond accuracy.